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# COMPARISON OF VARIOUS SIGHTING METHODS IN AERIAL COMBAT

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## INTRODUCTION

The problem of the advantages inherent in any one method of sighting in aerial combat cannot be solved by mathematics alone.

A comparison of the various possible methods of sighting utilizing a nonautomatic sighting device is more difficult than it may seem at first. Advantages and disadvantages are inherent in each method. The mechanical approach to the problem of comparison is especially dangerous. If we divide sighting into separate elements, calculate the errors arising from each one, take their sum by means of a mathematical apparatus utilizing the law of probability, and from the result determine the sighting, the magnitude of total error with each method will appear large. If, studying the magnitude of error in the measurement of the separate factors of an aerial encounter, we disregard given practices and assume that all errors are mutually independent, all the ensuing calculations will have no actual basis. The advantage of the law of probability, by means of which we usually determine the sum total of true deviations of a shell from the center of sighting, is that it permits the utilization, within its own mathematical apparatus of the observation results.

In determining the factors which enter the problem of the evaluation of any certain method of sighting, it is necessary that the problem be completely allied with actual practices. It therefore follows that an especially acute study of the interrelation of errors be made to show whether the method in question has the tendency to permit recurrent errors of a definite magnitude which abruptly change the whole picture of calculation. Only by



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such an approach, in which the law of probability is utilized in comparing methods of sighting, are we afforded an answer near the truth.

For example, in Comrade Pugachev's studies, A Comparative Analysis of Methods of Calculating Lead in Aerial Encounter, (published by VVIA /Military Air Engineering Academy/imeni Zhukovskiy, 1943) and Contemporary Methods of Sighting in Aerial Encounter and the Outlook for their Development (same publisher, 1945), we have found a very surprising deduction concerning the complete superiority of the fuselage method of calculating lead over the method of calculating in thousandths with the aid of a ring-type sight. The truth of the matter is that in practice the fuselage method of sighting is most impractical in distances over 200 meters.

What, then, is the reason for this paradox? We did not seek the answer among mathematical errors. We considered that Pugachev's error ought to be looked for in the principal formulation of the problem, in the formulas used, and in his actually unjustified hypotheses on the laws of distribution of error, as well as in the incomplete use of practical data.

Precisely at this point we decided to do again the work which had been done and state our own opinion on the problem of utilizing a given method of sighting in aerial combat.

Naturally, the present article makes no pretentions of being infallible and is in point of fact a discussion.

## I. PRACTICAL EVALUATION OF THE FUSELAGE METHOD AND THE RING-TYPE SIGHT METHOD

We shall analyse the thesis of Chapter I, "Characteristics of the Methods of Visual Calculations of Lead in an Aerial Encounter," of Pugachev's work, A Comparative Analysis of Methods of Calculating Lead in Aerial Encounter. On the subject of the necessity of calculating the target angle while using a ring-type sight for determining foreshortening of the target craft, the author states: "...determination of the foreshortening of an aircraft, especially foreshortening of present-day streamlined aircraft, offers us great difficulty. The aerial gunner can learn to detect foreshortening correctly only by thoroughly memorizing the foreshortening tables for all types of enemy aircraft. In order to recall these tables, the gunner must possess a very retentive memory." This thesis is not altogether valid. Rather than instruct the gunner in detecting the foreshortening of an enemy aircraft, we put greater stress upon his realizing that the foreshortening of an aircraft is that angle formed by the target craft's line of flight with the line of sight directed against the target craft rather than a projection of a certain type of aircraft in the firing area. We shall validate this thesis by citing examples of various types of aircraft with varied foreshortening.

For example, a foreshortening of 0/4 indicates that the enemy aircraft moves in a line toward or away from the gunner in such fashion that the angle between the line of flight of the target and the line of sighting directed against the target equals 0 degrees or 180 degrees. A foreshortening of 1/4 indicates that a small part of the aircraft's fuselage or tail structure appears in one-third of the field of vision, or drops below the periphery of the aircraft (the so-called "pitching"), or that it is projected above it with a small space between, etc.

For the gunner who is directing fire toward the rear hemisphere with a

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mobile gun, the foreshortening of an aircraft is computed so that if an enemy craft attacks the gunner's craft directly or a neighboring craft in battle formation the enemy craft will have an approximate foreshortening of 0/4. If the enemy craft attacks that craft ninth in line from the gunner, then the enemy's foreshortening will be 1/4. etc.

It is not necessary to recall foreshortening as a characteristic of a certain type of aircraft. Thus, we feel that the difficulty in detecting the foreshortening of an aircraft has been overestimated. It is unnecessary to demand that an aerial gunner possess an extremely retentive memory, but rather that he understand fully what foreshortening is, and that he undergo constant training in its determination, based on concrete examples of aircraft types and not on target craft type.

Detection of a target's foreshortening is not required with the fuselage method of firing, which fact constitutes its undeniable superiority.

The author states: "The disadvantage of the fuselage method is the necessity of determining distance, since linear lead varies sharply with a change in distance." But in the author's opinion the problem is simplified by the fact that the linear lead varies proportionally with the distance. Therefore, the gunner needs only to remember the number of lengths for firing at a distance of 100 meters for a certain type of aircraft, and increase this number of lengths proportionally with the distance. We shall analyze in detail the degree to which the necessity for a periodic change for every 100 meters of the distance affects the accuracy of sighting.

As an example, let us take the case of fire directed against a fighter aircraft, whose fuselage length Pugachev assumes to be about 8 meters. The basic data for the computation are obtained as follows: $V_{ts} = 540$ km/hr = 150 meters/sec (TN: $V_{ts} = V_{target}$); initial velocity $V_o = 850$ meters/sec; reduced ballistic coefficient $C = 3$. The linear lead is determined by the familiar formula: $L = V_{ts} \cdot t = \frac{V_{ts}}{V_{gr}} \cdot D$ (TN: $V_{gr} = V_{gunner}$) and will consequently equal: for a distance of 100 meters, L = 18.5 meters; for a distance of 200 meters, L = 38.8 meters; for a distance of 400 meters, L = 86 meters, etc. In order to obtain the lead expressed in a number of lengths, it follows that we merely divide the linear lead obtained for a certain distance by the length of the fuselage; that is, $n = \frac{L}{L_f}$. As a result, for a distance of 100 meters we obtain n = 2.5; for a distance of 200 meters, n = 5; for a distance of 400 meters, n = 11; for a distance of 600 meters, n = 16 lengths; etc.

Let us assume that this target is being fired on by the gunner of a bomber whose speed is approximately 360 km/hr. In this case the distance between the target and the gunner is decreasing at the rate of 55 meters/sec, and over a period of 6 to 7 seconds, the distance has decreased from 600 meters to 200 meters. During this time the gunner must decrease the number of lengths considered as the lead from 16 to 5, diminishing the quantity by 2.5 lengths for each 100 meters of decrease in the distance. In so doing he can utilize all the advantages of the relation between the distance to the target and the number of lengths considered as the lead.

It is completely impossible not to have an error of from 40 percent to 50 percent in determining the distance and sighting of a lead assumed to be 16 lengths. Moreover, the necessity for the periodic change of distance to the target and the corresponding diminution in the number of lengths in the lead present the gunner with a very great, if not insurmountable, hardship. We thus feel that in the example given, which appears to be most typical, the average gunner, unable to utilize the angular method of sighting, would in

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actual practice fire at will or else fire merely by pointing.

This last conclusion can be supported by the following considerations.

In the first place, the majority of fighter planes produced by present-day manufacturers, including even the jet-propelled types, have fuselages of from 7 to 14 meters long, while the fuselage length of bombers and ground-attack aircraft of the present day varies from 12 to 30 meters depending upon the type. Thus, to utilize the fuselage method, it would be necessary for the gunner to have an especially retentive memory merely to determine the length of the enemy aircraft's fuselage.

Thus, the practice has arisen of considering the basic fuselage length of fighter craft to be 10 meters, and that of bombers 20 meters, which, naturally, leads to error.

In the second place, as the maximum speeds of fighter craft have increased up to 700 or 800 km/hr and even faster, the linear lead has also increased. For example, with a fuselage length of 8 meters at a distance of 600 meters it is necessary to assume not 16 lengths, which was the quantity necessary to assume for a target moving at a speed of 540 km/hr, but a much greater quantity. With the velocity of the target equal to 700 km/hr, the lead is 22 lengths, and with a velocity of 800 km/hr it equals as much as 30 lengths. It is impossible to sight with such a lead without admitting gross errors. In spite of this, however, at least 500 to 700 meters is considered the requisite combat distance. At this distance the gunners of the attacking bombers open fire while the speed of the enemy is 500 to 600 km/hr. And, as far as the fighter pilots are concerned, increasing the speed of the aircraft produces a sudden diminution of the attack's duration and consequently makes it necessary to open fire on the enemy at distances ranging from 400 to 600 meters.

In addition, diminution of the duration of aerial combat to as little as 4 or 6 seconds does not afford the gunner the time to deal with the continuous determination of distance.

After observing gunners sighting in training we may state that those gunners using the K-8T sight were much more confident and had far better results than those using the OP-2L sight, with its fuselage-length method for calculating the lead, even if we disregard the necessity of have to calculate one's own speed in utilizing the latter. In training, aerial gunners sighted more accurately with the ring-type sight calibrated in thousandths than with the fuselage method, even though they had sufficient time for sighting and the problem of distance could be determined very accurately under the simulated conditions of training.

As early as the beginning of 1943, we found it necessary, in our air units, to measure the angular value on the graduated scale of the OP-2L-type sight in order to determine the distance to the target, and mentally to conceive the visual field of the OP-2L-type sight in thousandths. We discovered that with foreshortenings of 0/4, 1/4, and 2/4, the radio operator gunner sighted much more effectively with the OP-2L-type sight (in which there are no lead rings measuring the lead in thousandths) than by adapting the fuselage method of calculating the lead to this type of sight. Thus, the fuselage method of sighting was superseded in 1943. Meanwhile, several other air units had availed themselves of the successful results of our investigations and experiences in utilizing this OP-2L-type sight for firing by the method of angular lead as a possible substitute for the fuselage method.

As far as the problem of having to calculate distance in aerial combat is concerned, we need only introduce tactical considerations. In the first place,

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it is necessary to calculate the distance to the point of appearance of the enemy in the field of vision, and then to calculate the distance for opening fire. After the first immediate repulse of the attack, the gunner does not have sufficient time to correct his distance reading with a sight graduated for range finding. There is only time to readjust the training of the gun after each burst of fire.

## II. THEORETICAL EVALUATION OF ACCIDENTAL ERRORS

Pugachev proceeds from the hypothesis that the gunner will round off the value of the measured distance to the nearest hundred meters admitting no error greater than 50 meters. He considers all errors within this range to be problematically equal. Thus, he claims, with an increase of the distance to the target, the relative error in calculating the distance decreases. In actual practice this is not at all true. The greater the distance, the greater the error the gunner introduces in his calculations. However, it appears impractical to us to establish a general law for the distribution of error in the calculation of distance in all ranges of aerial combat from 700 meters to 100 meters.

Let us examine aerial combat involving three ranges: (1) 700 to 500 meters; (2) 500 to 200 meters; (3) 200 meters and less. It will then be nearer to the actual facts to assume that in the third case the gunner does not introduce any error of absolute value of more than 50 meters in calculating the distance, and that he will round off the value of the distance to the target to the nearest hundred meters, that is, he will take either 200 meters or 100 meters as the distance. Consequently, in the third case we may admit the law of equal probability for the distribution of error. In the second case we propose that the law of distribution of error in the determination approaches Gauss's Law and that an error greater than 100 meters is not very probable. In the first case we also assert that the distribution of error conforms to Gauss's Law, which shows that an error of more than 150 meters has little probability.

Computation of the problematical deviations during analysis of the various methods of sighting will permit us to determine accurately within which of the above-mentioned ranges of distance a comparison can be made.

According to Gauss's Law, a deviation of the point of impact from the center of dispersal greater than four times the probable error is considered practically impossible. Having determined a maximum error of 150 meters in the first case and dividing it by 4, we obtain the size of probable error in calculating the distance: in the first case $E = 37.5$ meters, and in the second case $4E = 100$ meters and $E = 25$ meters.

Pugachev does not point out the other specific accidental errors of the fuselage method. This is the key to his erroneous deduction concerning the advantages of the fuselage method of calculating lead over calculation by angular lead in thousandths.

The gunner always introduces a systematic error in computing the distance. Actually, the moment he has calculated the distance to the target he must compare a certain number of lengths with it, plot them from the nose of the target craft and depress the thumb trigger. In this way, from the moment the distance to the target is determined to the moment of firing there is a lapse of at least 0.5 seconds. During this time the distance has decreased 30 to 40 meters.

Pugachev later remarks that the gunner, in determining the distance, plots the exact number of lengths corresponding to the computed distance. Setting



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aside the considerations cited earlier concerning the great difficulty inherent in calculating the linear lead in fuselage lengths, we shall cite still another completely unavoidable error characteristic of the use of the fuselage method. The gunner is not able to plot the exact number of lengths (n) corresponding to the distance he has calculated. Error in the number of lengths plotted is inevitable since it is impossible to plot the exact number of lengths by eye and, in addition, the fuselage length of the target craft depends on the position of the gunner. It is practically impossible to give a law for the distribution of this error which would hold true for all distances of aerial combat. In this case it is much more appropriate to propose the existence of laws of distribution similar to Gauss's Law, with various probable deviations depending upon the various ranges of aerial combat. Let us base our observations on the same cases of aerial combat which we utilized above. If a target fighter craft has a speed approaching 600 km/hr, then in the first case--at distances up to 500 meters--the utilization of the fuselage method is not generally expedient since one must plot more than 16 lengths, a process difficult to carry out even with great error. In any case, an error greater than 10 fuselages would not be practical. In this case the probable error is 2.5 F.

In the second case assuming six fuselages as the maximum possible error, we derive the probable error $E = 1.5$ F. In the third case assuming three fuselages as the maximum possible error, $E = 3/4$ F.

Let us pass on to the determination of the lower level of the probable error for firing with a ring-type sight. Pugachev asserts that the gunner "can round off the value for sin q in integral fourths without introducing errors in the value for sin q, greater than the absolute value of 1/8." It is not necessary to argue this point as the more or less experienced gunner will not introduce an error greater than a foreshortening of 1/8. Then the mean square deviation of the sine of the target angle conforms to the law of similar probability $E_{2q} = \frac{1}{8\sqrt{3}} = 0.072$, and the conventional, corrected probable error $E_q = E_{2q} \cdot \rho\sqrt{2} \approx 0.049$. We do not find greater specific errors in firing with the visual ring-type sight. In this case the gunner is in no way impeded in plotting (with the ring-type sight) the number in thousandths corresponding to the foreshortening of the target, since the sight's ring is calibrated for typical speeds and foreshortenings of fighters and bombers.

We have investigated errors in the measurement of several factors which determine the guide points for sighting at an enemy aircraft. We are also interested in the total dispersion. In order to calculate the latter, we can utilize the principles which constitute laws on the distribution of accidental values. Since we have assumed that the errors arising from calculating various factors conform to Gauss's Law, and that in those instances where the law of equal probability is encountered we introduce the concept of the conventional, reduced probable error, then, consequently, we have a perfect right to employ the sufficiently adequate formula which constitutes Gauss's Law.

We are forced to observe that this method is far from perfect and that it is not completely capable of representing the actual value of dispersion, since that depends upon the mutual independence of all component laws and does not take into account the emergence of systematic errors. As a matter of fact, independence in the determination of the deduced factors for the calculation of the sighting point does not exist in aerial combat. For example, it is clear that errors in computing the value for distance produce all the other errors which arise in calculating the deduced factors. The greater the distance, the greater the error will be in computing its value, the greater the error in the number of lengths plotted, the more difficult it will be to identify the enemy aircraft, determine its speed, over-all demensions, etc.

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Moreover, we have omitted from our account those important components related to slowness of the gunner's reflexes, the conditions of aerial combat, atmospheric conditions, etc. But, for the present, the theory of aerial firing has not produced a better means of determining total dispersion, and we shall calculate the total probable error in the same manner utilized by Comrade Pugachev.

We must also note that the most natural means of determining total probable error is by measuring the results of experimental firing under widely varying conditions. However, the difficulty inherent in this approach is self-evident.

Let us pass on to the derivation of formulas dealing with probable error in dispersion with the fuselage method for calculating lead.

## III. THEORETICAL COMPUTATION OF DISPERSION WITH THE FUSELAGE METHOD OF CALCULATING LEAD

In presenting briefly the method for computing total probable error we shall utilize Comrade Pugachev's diagram. The technical dispersion $E_t$ is represented by a circle. Dispersion due to inaccuracy in determining the target's plane of flight is designated as $E_n$. Dispersion due to inaccuracy in determining the target's velocity is designated as $Ev_{ts}$. It is evident that the probable errors of $E_t$, $E_n$ and $Ev_{ts}$ are the same for both comparative methods of sighting. It is assumed, moreover, that the errors arising from the measurement of the factors of firing are mutually independent. These factors of the formulas for total diffusion have no part in the solution of the principal problem concerning the advantage of one of the means under analysis over the other, since they are similar for both conditions.

The center of the axes of dispersion is laid out, let us assume, at the point of impact, and the axes themselves are arranged in a plane perpendicular to the line of sight toward the point of impact. The X axis is described by the track of the intersection of the plane of the lead triangle with the plane of our diagram. Let us accordingly set the Y axis perpendicularly above the X axis. Now let us ascertain the total dispersion along the X axis in the case of utilization of the fuselage method for calculating linear lead (Figure 1).

The linear lead is, as we know, expressed by the formula:

$$L = V_{ts} \cdot t = \frac{V_{ts}}{V_{sr}} \cdot D.$$

Due to an error in measuring distance, the gunner also introduces an error in the determination of linear lead.

$$(L + \Delta L) = \frac{V_{ts}}{V_{sr}}(D + \Delta D),$$

from whence the error in the linear lead will be

$$\Delta L_D = \frac{V_{ts}}{V_{sr}} \Delta D \quad \text{(Figure 2).}$$

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Projecting this error on the X axis we will have:

$$X_{\Delta D} = \frac{V_{ts}}{V_{sr}} \Delta D \cdot \sin (q + \psi) \approx \frac{V_{ts}}{V_{sr}} \sin q \cdot \Delta D.$$

But since

$$\psi = \frac{V_{ts}}{V_{sr}} \sin q$$

is small in comparison with q, we obtain a functional relation between the projection of the error in the linear lead and the error in distance:

$$X_{\Delta LD} = pr \cdot x \Delta L_D = \psi \Delta D.$$

The law of probability gives us, as the result of such a functional relation, a relation between the probable errors:

$$E_{XD} = \psi E_D \cdot$$

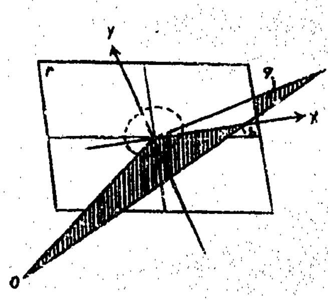


Figure 1

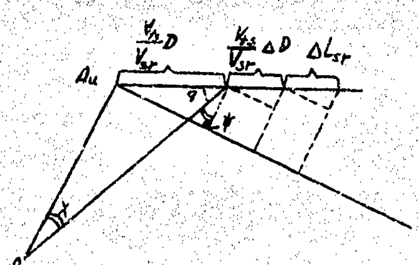


Figure 2

An error in the linear lead due to an incorrect total number of lengths and to inaccuracy in calculating their dimensions is projected directly on the X axis, $X_{lf} = \Delta LF \cdot \sin q$, and the corresponding probable error will be $E_{xlf} = \sin q \cdot \bar{E}_{lf}$.

Finally, we add the error in the linear lead due to error in calculating the speed of the target:

$$\Delta Lv_{ts} = \frac{\Delta V_{ts}}{V_{sr}} \cdot D.$$

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Projecting this error on the X axis, we obtain:

$$Xv_{ts} = pr \cdot x \Delta L_{ts} = \frac{D}{V_{sr}} \sin q \cdot \Delta V_{ts}.$$

Multiplying the numerator and denominator by $V_{ts}$ and interpolating the angle of lead $\psi$, we obtain

$$Exv_{ts} = \frac{\psi D}{V_{ts}} \cdot Ev_{ts}.$$

To obtain the total probable error we use the theory of the law of distribution of the sum of several independent, accidental values which conform to Gauss's Law. The ultimate law will thus be Gauss's and the total probable error will give the formula:

$$E^2 = \sum_{i=1}^{n} E_i^2, \text{ where } i = 1, 2, \ldots n.$$

In our case the total probable error along the X axis, when utilizing the fuselage method of computation, is expressed by the formula:

$$\frac{E_x}{D} = \sqrt{E^2_T + \psi^2 \left(\frac{E_D}{D}\right)^2 + \left(\frac{E\,L\,f}{D}\right)^2 \sin^2 q + \psi^2 \frac{(E_{vts})^2}{V_{ts}}}, \qquad (1)$$

where all probable errors are expressed in angular measurement.

The dispersion along the Y axis due to inaccurate calculation of the plane of flight of the target is determined as shown in Figure 3.

Let us project the linear lead on the X axis:

$$pr \cdot xL \frac{V}{V} D \sin (q + \psi) \approx D \frac{V_{ts}}{V_{sr}} \sin q = D\psi.$$

Then the error due to inaccuracy in calculating the plane of flight $\Delta\delta$ would be $Y = D\psi\Delta\delta$, whence $E_{y\delta} = D\psi E_\delta$, or expressed as an angle $\frac{E_{y\delta}}{D} = \psi E_\delta$,

and the total dispersion along the Y axis appears as:

$$\frac{E_{y\delta}}{D} = \sqrt{E^2_T + \psi^2 E^2_\delta}.$$

The semiaxes of the dispersion ellipse conforming to Gauss's Law will be equal to:

$$a = 4\,E_x$$

$$b = 4\,E_y$$

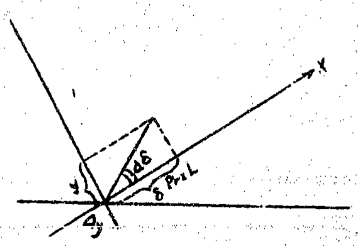

Figure 3

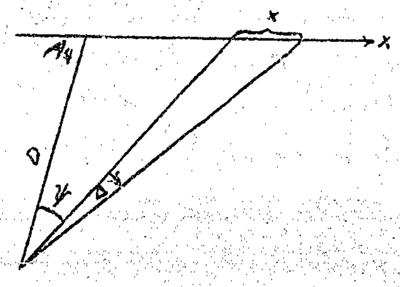

Figure 4

Formula (1) does not differ from the one obtained in Pugachev's work only by the presence of the term $(\frac{-E_{1f}}{D})$ sin q. In this formula the term $(E_n)^2$ is absent. In Pugachev's work, E is the probable error resulting from inaccuracy in plotting the line of sight or else the angular probable error in training. This term is found, without exception, in all formulas dealing with total probable error and apparently explains why the gunner, in calculating the location of the point of sight in the sighting device, is unable to locate the target accurately with it.

It is clear that neither the fuselage method of calculating lead nor the method of sighting with a ring-type sight has any characteristic errors along the Y axis which would give one an advantage over the other. However, let us suppose that the error represented as $\Delta\delta$ depends in great measure on the direction of flight of the attacking or the attacked aircraft in relation to the gunner's aircraft. As a matter of fact, both the means of sighting described by us demand that the aerial gunner accurately locate the axes of the fuselage of the enemy aircraft in the center of the sighting device. At the same time the enemy aircraft usually, and particularly when approaching for attack, moves, in relation to the gunner, in such fashion that the visual movement of the aircraft rarely if ever corresponds to the position of its fuselage. This results in large errors especially when firing from movable installations and when concentrating fire in the rear hemisphere. The gunner instinctively wishes to locate the visual movement of the target in the center of the sight and not the position of its fuselage, which is very often difficult to determine with the naked eye.

The norms of dispersion utilized by Pugachev do not show the effects of relative movement of the target upon accuracy of sighting while directing fire in an aerial encounter.

## IV. THEORETICAL CALCULATION OF DISPERSION IN FIRING WITH A RING-TYPE SIGHT

Error in the lead angle $\Delta\psi$ due to error in calculating the target angle $\Delta$ sin q is equal to $\Delta\psi = \frac{V_{t.s}}{V_{sr}} \cdot \Delta \sin q$, by which the linear error along





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the X axis will approximately equal: $X \approx D \triangle \psi = D \frac{V_{ts}}{V_{sr}} \triangle \sin q.$

Consequently, the probable error along the X axis owing to inaccuracy in calculating the target's foreshortening will be $E_{xq} = D \frac{V_{ts}}{V_{sr}} E_q$ (Figure. 4), and we can obtain the total probable error with the error of calculation in determining the speed of the target by the formula:

$$\frac{E_{\lambda}}{D} = E_T^2 + \left(\frac{V_{ts}}{V_{sr}}\right)^2 E_q^2 + \psi^2 \left(\frac{Ev_{ts}}{V_{ts}}\right)^2,$$

where the probable error is proportional to the distance. Dispersion along the Y axis is expressed by the same formula as for the fuselage method.

## V. COMPARISON OF THE FUSELAGE METHOD OF SIGHTING WITH THE RING-TYPE SIGHT FROM THE VIEWPOINT OF ACTUAL FIRING

We have now only to compare, with examples, the ring-type method of sighting with the fuselage method. In order that he may at once convince the reader of the obvious advantage of the fuselage method, Pugachev solves the problem in firing with the target angle equal to zero. Inasmuch as the formula for the total dispersion with the fuselage method, as presented by Pugachev, does not contain a term which is related to $\Delta I_F$, but obviously one related to sin q, we quickly obtain minimum dispersion along the X axis in the case where $q = 0$. At the same time, in spite of the fact that the value of the target angle equals zero, the formula of total dispersion for a case of sighting with a ring-type sight clearly points out a fundamental error in calculating a foreshortening equal to 1/8 We are forced at once to remark that the example in which $q = 0$ is not representative and does not afford a common ground for comparing the methods of sighting. The reason for this is as follows: with target angles deviating from 0 to 5-7 degrees and from 180 to 175-173 degrees, the gunner can use no other means of sighting than firing by mere training of the weapon. Any aerial gunner will testify to this fact. Consequently, in beginning to compare the two methods it is necessary that the target angle q equal 15 degrees, that is to say, there must be a foreshortening of 1/4.

In this fashion one might cite a whole series of examples of calculating the total probable error in both means of sighting and, comparing them for the manner in which they satisfy various firing conditions, decide upon the efficiency of this or that method. The question of the advantages of one of the two methods cited is solved, naturally, by the use of that one whose specific errors are least encountered.

It is necessary to study these calculations in order to see whether mathematics, utilizing more justifiable practical formulas, gives greater advantages to the fuselage method of calculating lead. For our part, actual aerial firing solved in principle the problem concerning the advantages of the method of sighting with the ring-type sight in thousandths as compared with the fuselage method.

We shall not investigate the method of sighting based on a calculation of the relative movement of the target aircraft. The development of contemporary aviation engineering permits us to assert that sights of new design will solve this problem automatically.

- END -